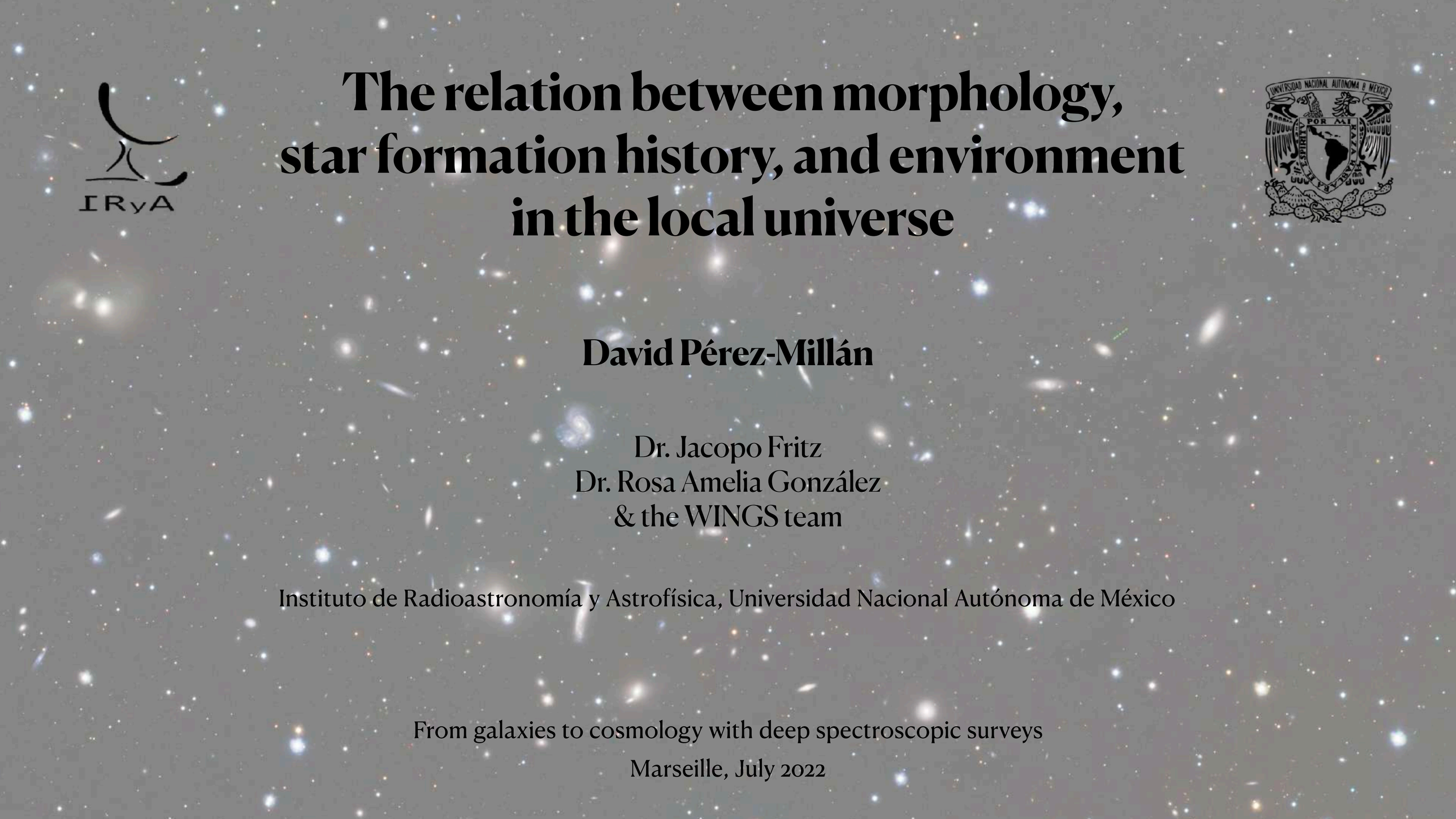

The relation between morphology, star formation history, and environment in the local universe

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From galaxies to cosmology with deep spectroscopic surveys

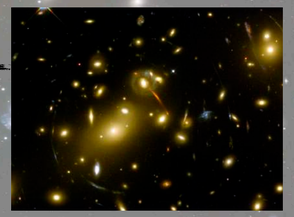
Marseille, July 2022

Galaxy evolution

Galaxies in local clusters are spheroidal and quenched

The ICM

The cluster as a whole



Which is the cause?

The high galaxy density

...or all of them

What is the path that leads them to not form stars?

?

Environment

Goto et al. (2003)

Morphology

Calvi et al. (2018)

SFR/SFH

Stellar mass

Liu et al. (2019)

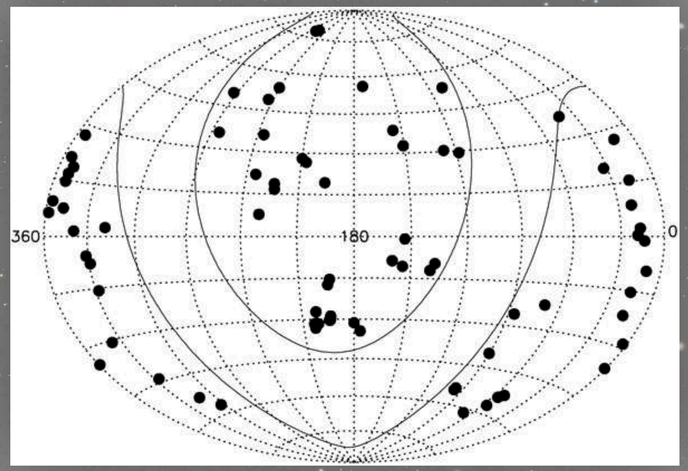
The data

WINGS/OmegaWINGS

Wide-field Nearby Galaxy-cluster Survey (Fasano et al, 2006)

Cluster sample (L_X complete)

- $\log L_X\ [0.1-2.4\ \text{keV}] = 43.2-44.7$
- $0.04 < z < 0.07$
- $|b| > 20^{\circ}$



Fasano et al. (2006)

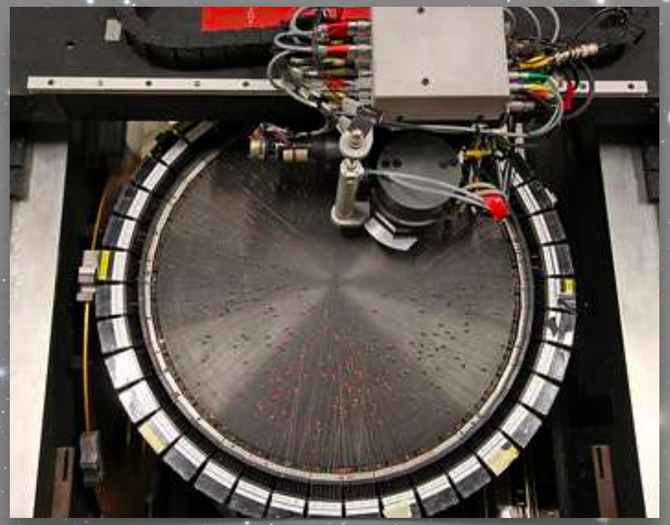
Previously-measured quantities

- ✓ **B, V photometry** $\sim 759{,}000$ objects (Varela et al., 2009; Gullieuszik et al., 2015).
- ✓ **Redshift** and **membership** (Cava et al., 2009; Moretti et al., 2017).
- ✓ **Cluster velocity dispersion** (Biviano et al., 2017), **X-ray luminosity** (L_X), and viral radius (R_{200}).
- ✓ **Morphology** $\sim 40{,}000$ objects (MORPHOT; Fasano et al., 2012).
- ✓ **Local density** $\sim 66{,}000$ galaxies, $\Sigma_{10} = \frac{N}{A}$ (Vulcani et al., 2012).

Spectra

- Range: $\lambda \sim 3600 - 8000\text{Å}$
- Resolution: $FWHM = 3 - 9$ Å
- Fiber diameter: $\sim 2''$

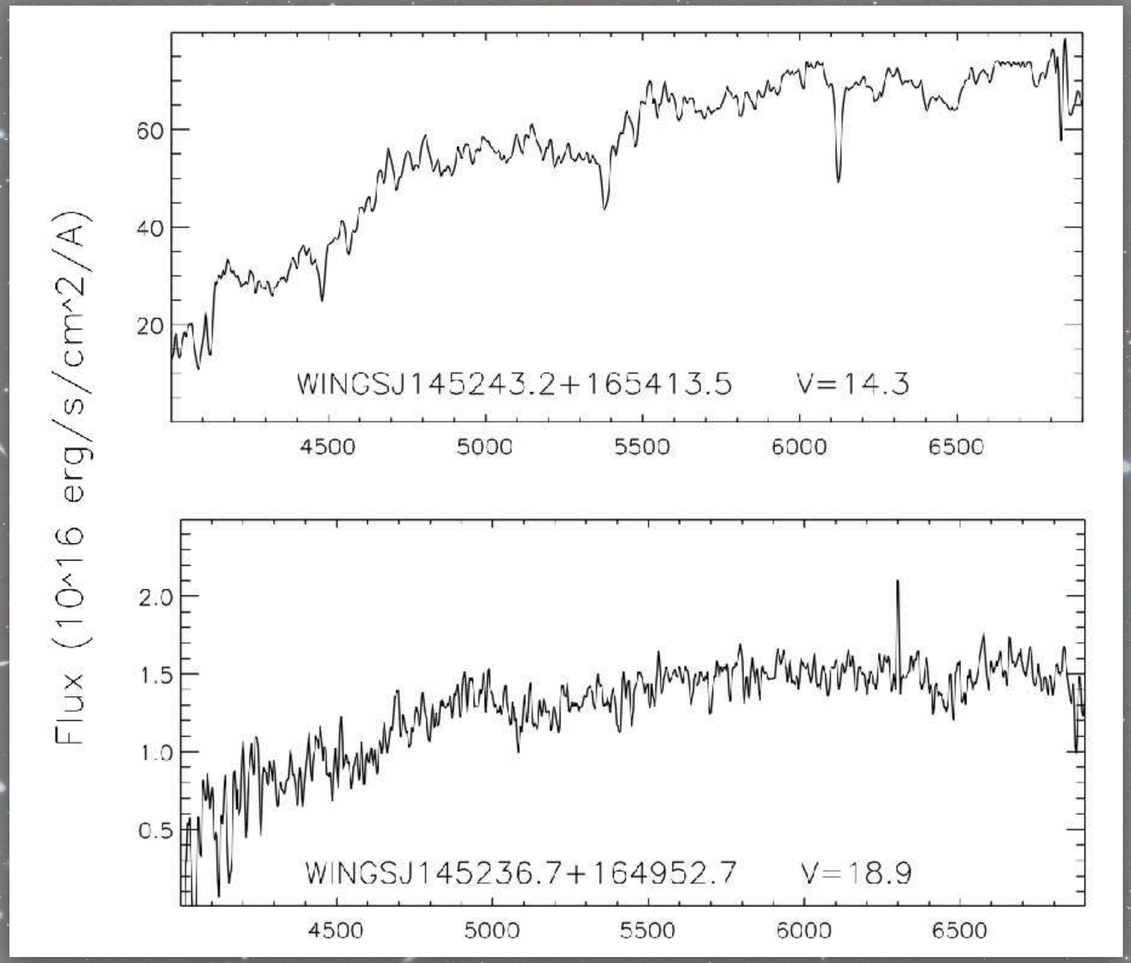
Aperture diameter: $2 - 3$ kpc



The 2dF robot gantry moving and positioning the optical fibers

https://angelrls.wordpress.com/2014/05/06/a-2df-night-at-the-aat/

Example of spectra observed with WYFFOS



Cava et al. (2009)

SINOPSIS

SImulatiNg OPtical Spectra wIth Stellar population models

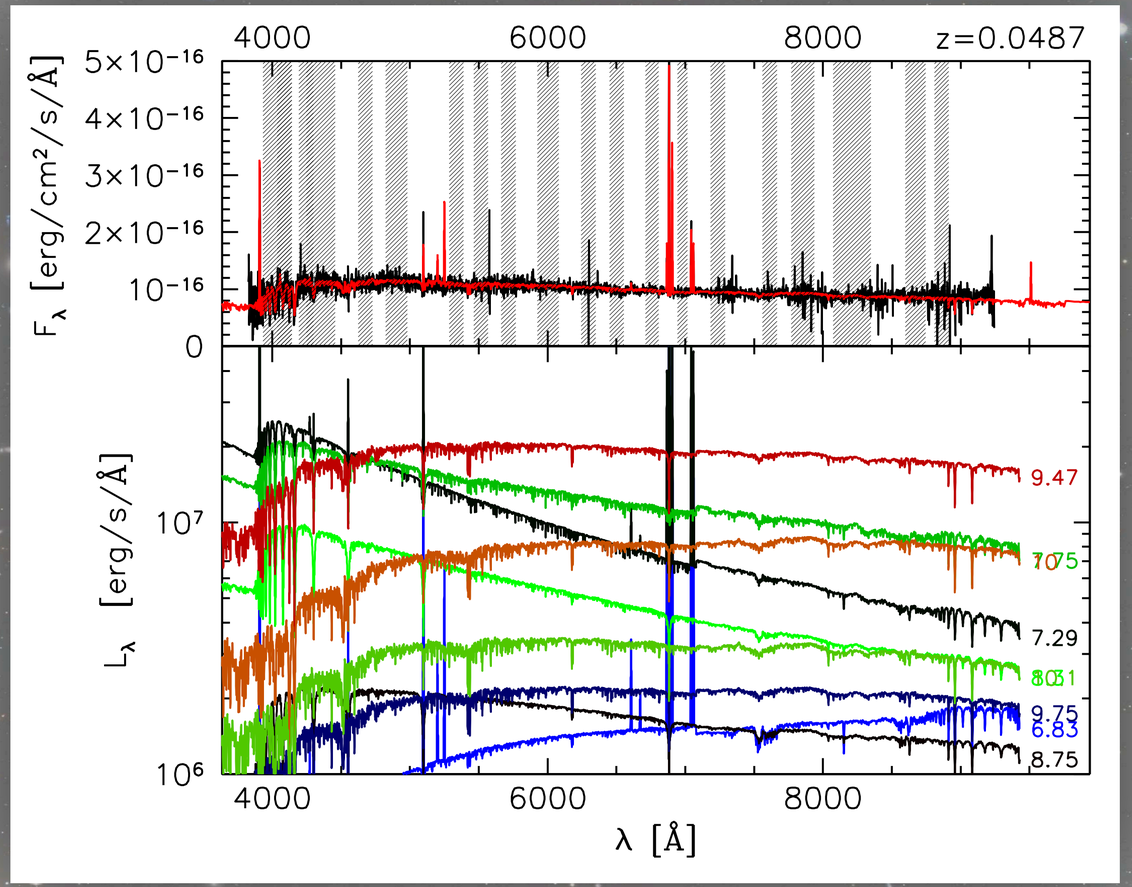
(Fritz et al. 2007, 2017)

How does it work?

- Observed spectrum
- Measures continuum flux and EW of emission and absorption lines
- SSP models with nebular emission lines, plus selective extintion
- Non-parametric SFH prescription

Derives stellar populations properties of galaxies:

- $SFR\ (t)$
- Mean stellar ages
- Stellar mass
- Dust extinction



Fitting example (SDSS)

The adopted setup

- SSP models: theoretical spectra of Charlot & Bruzual (in prep.).
- IMF: Chabrier (2003), stellar masses: $0.1 - 100\ M_{\odot}$.
- Selective extinction: average MW.
- Metallicity: 4 values:
  - Sub solar: $Z = 0.004$
  - Solar: $Z = 0.017$
  - Super solar: $Z = 0.03,\ 0.04$
- The oldest possible SSP is compatible with the universe age at the given z.

Star formation history bins

SFR_i	Age range	Age bin
SFR_1	$0 - 19.95$ Myr	19.95 Myr
SFR_2	$19.95 - 571.5$ Myr	551.55 Myr
SFR_3	$0.5715 - 5.754$ Gyr	5.183 Gyr
SFR_4	$5.754 - t_u$ Gyr	Δt_u Gyr

We ran SINOPSIS for 12,353 spectra

Sample selection

Cluster sample

✓ Cluster members: $\pm\ 3\sigma_{cl}$

✓ $\mathscr{M}_* > 3 \times 10^9\ M_\odot$

Total: 44 clusters, 4,349 galaxies (9601 weighted)

Field sample

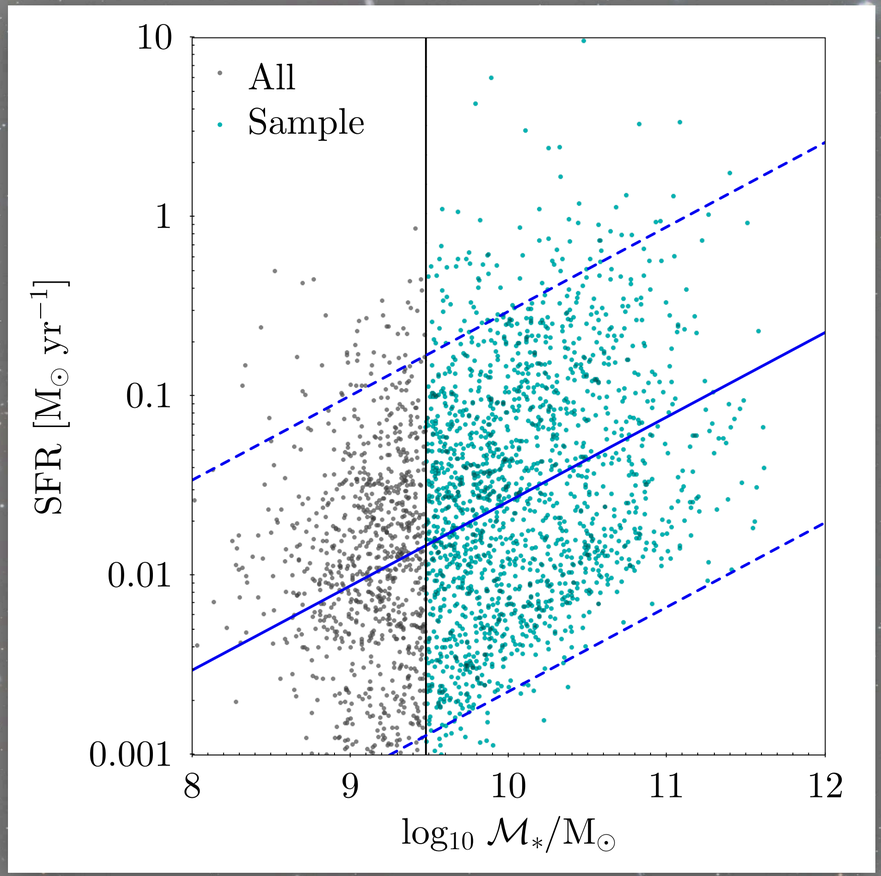
✓ Non cluster members

✓ $\mathscr{M}_* > 3 \times 10^9\ M_\odot$

✓ $0.02 < z < 0.09$

Total: 677 galaxies (1,071 weighted)

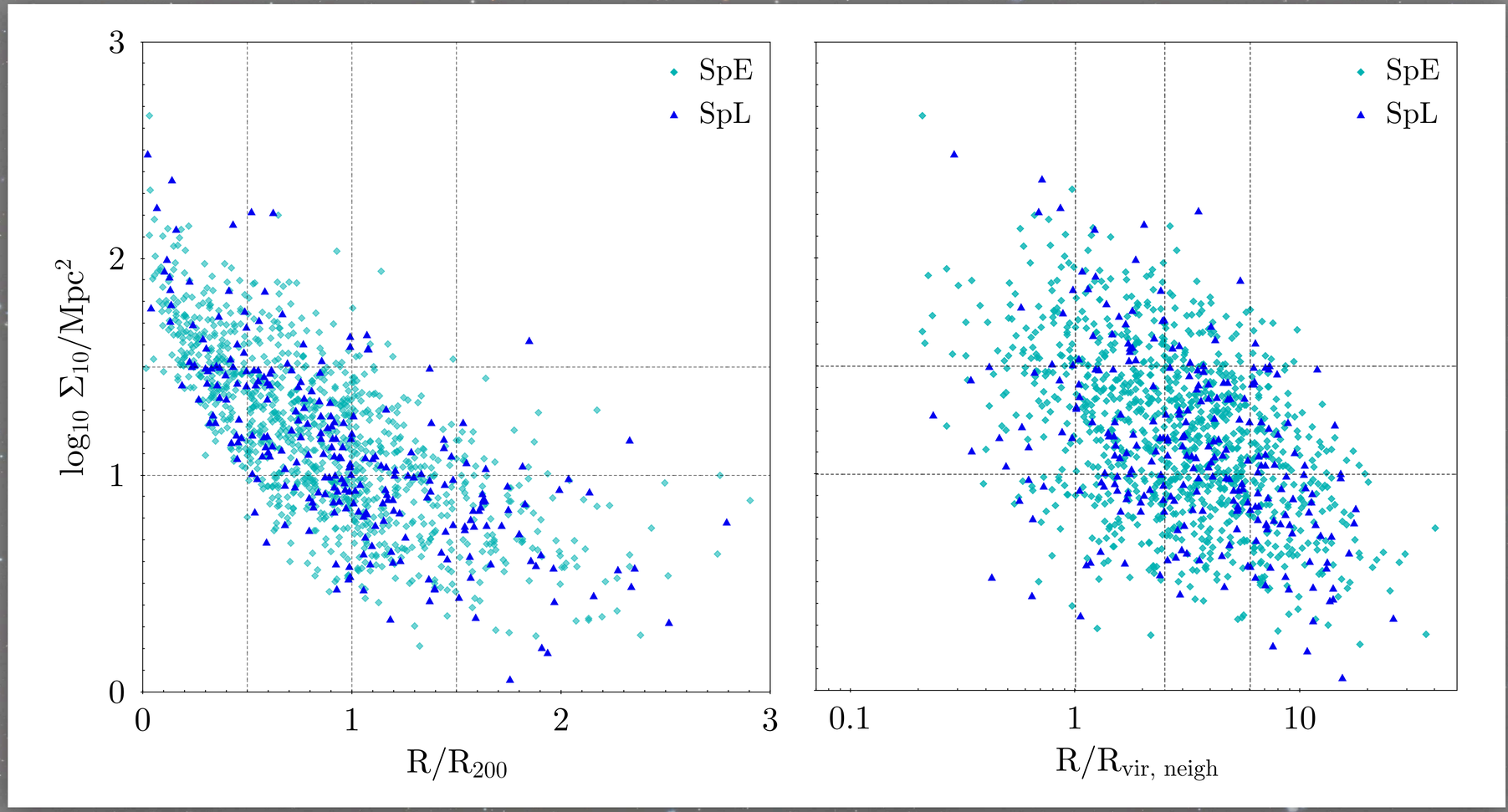
SFR-Mass relation



SF-active cluster galaxies

Environment parameterizations

Local density

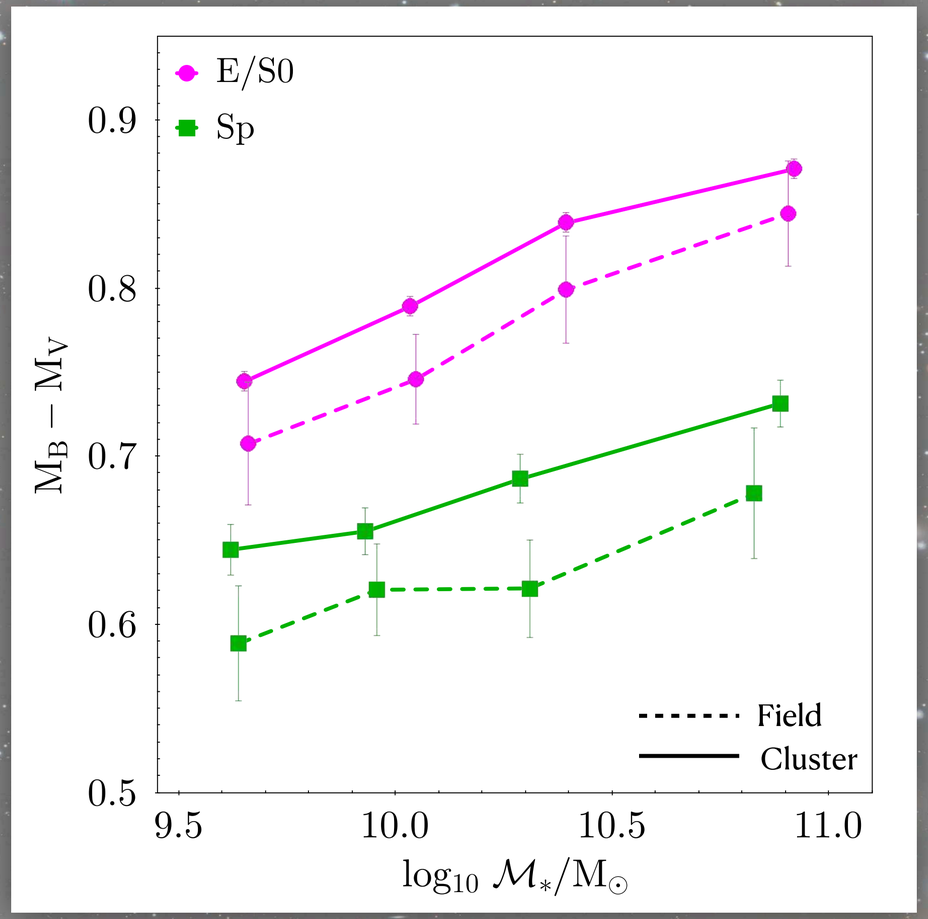


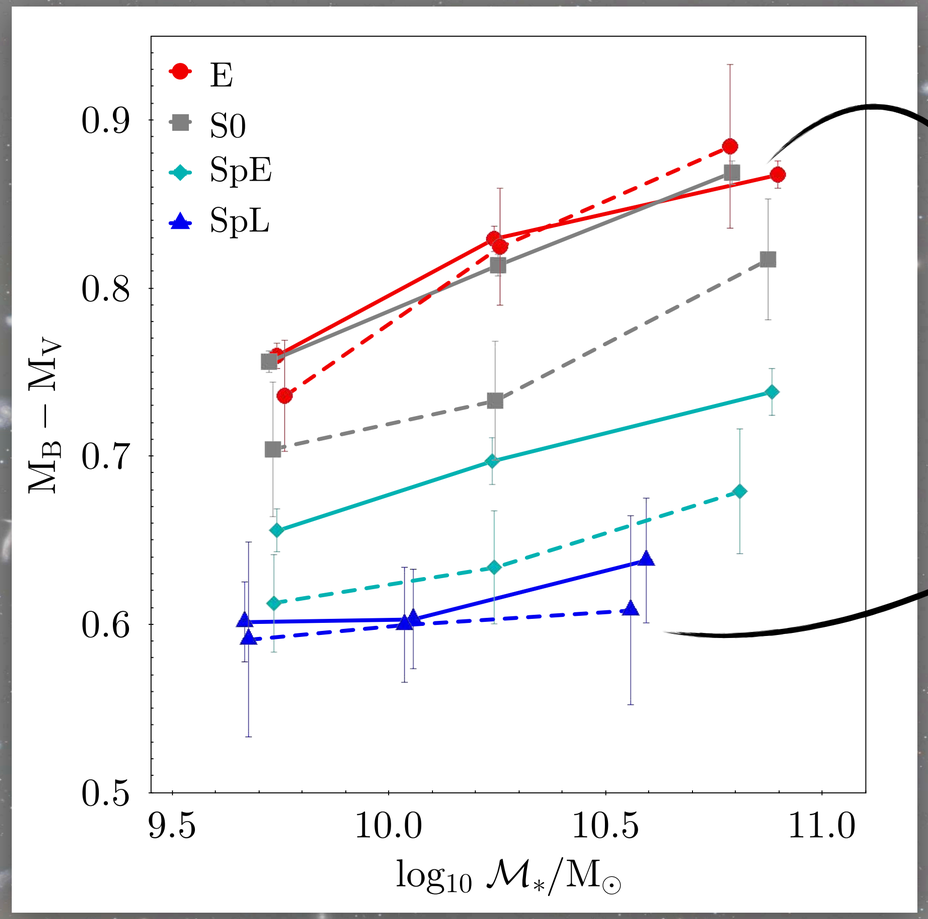
Projected distance

Closest neighbor

Results

Color-mass relation

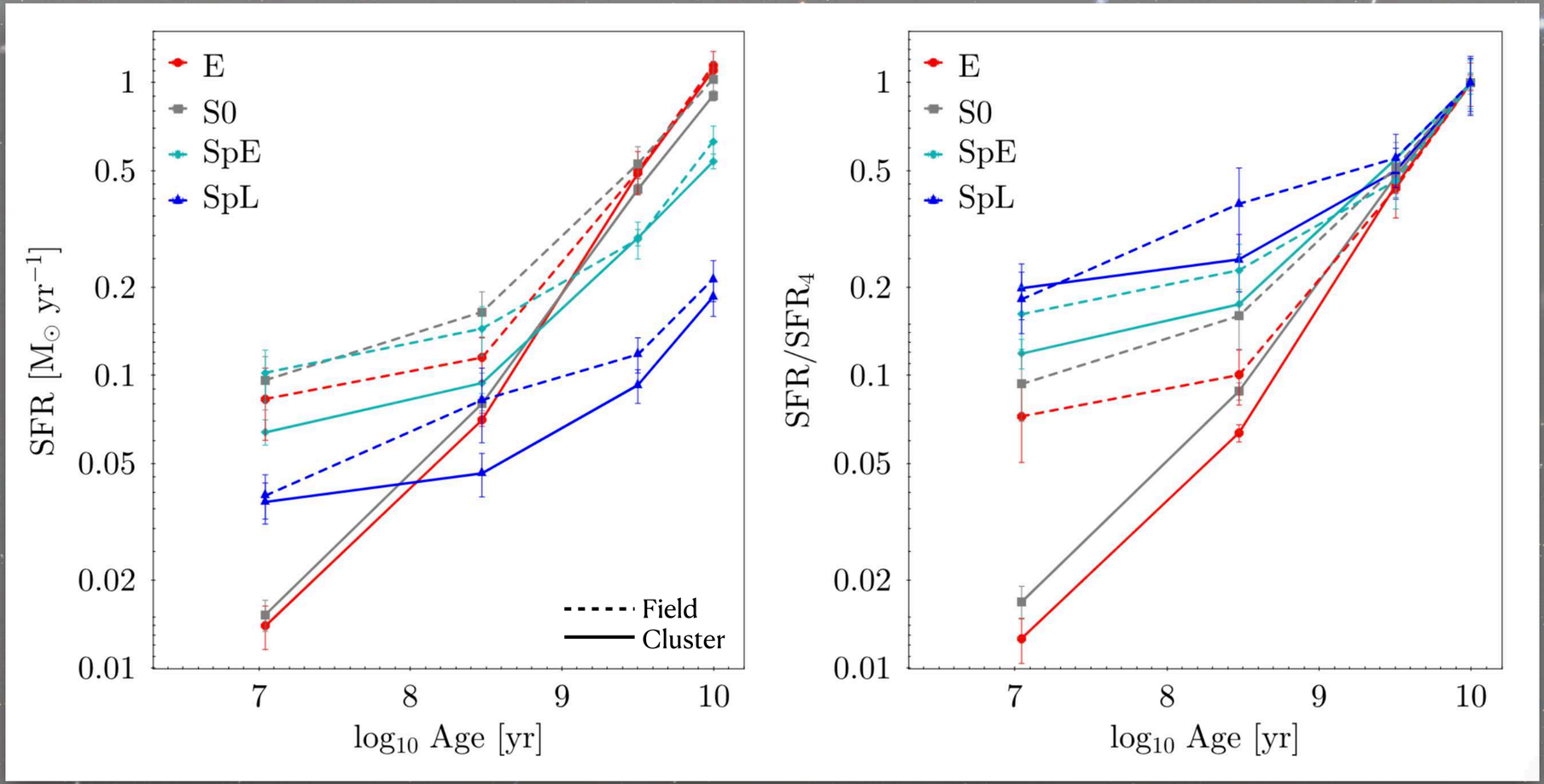




Ellipticals and late spirals are very similar in clusters and the field

SFH and morphology

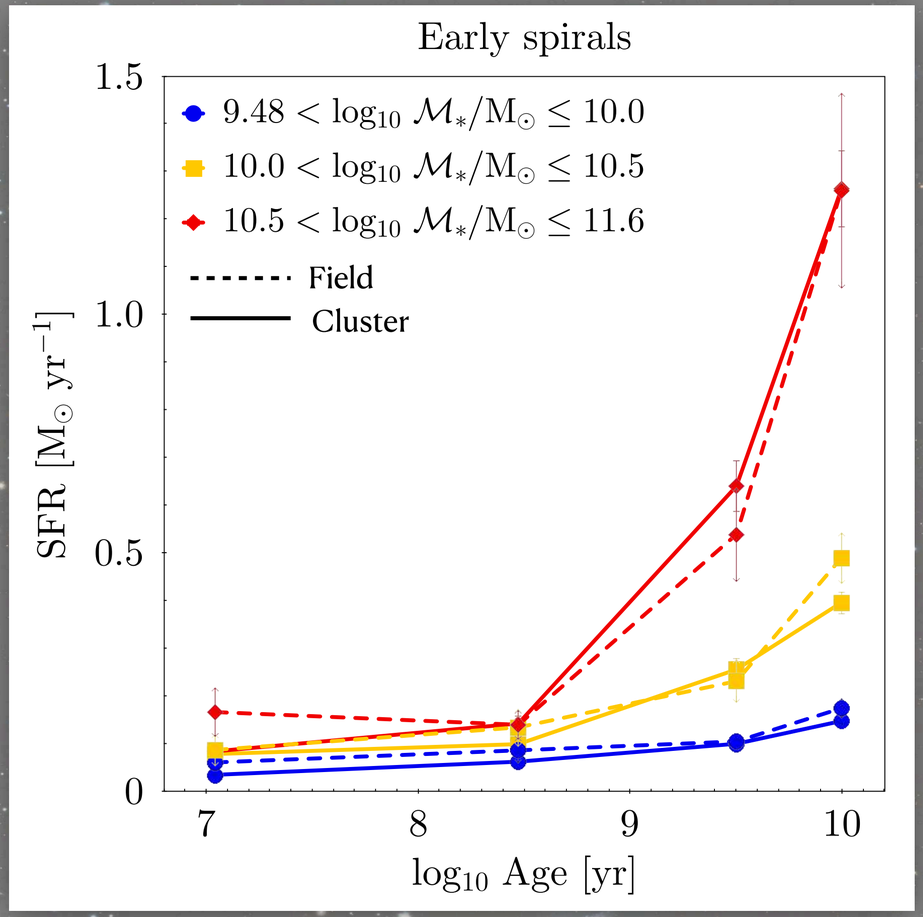
time ⟵



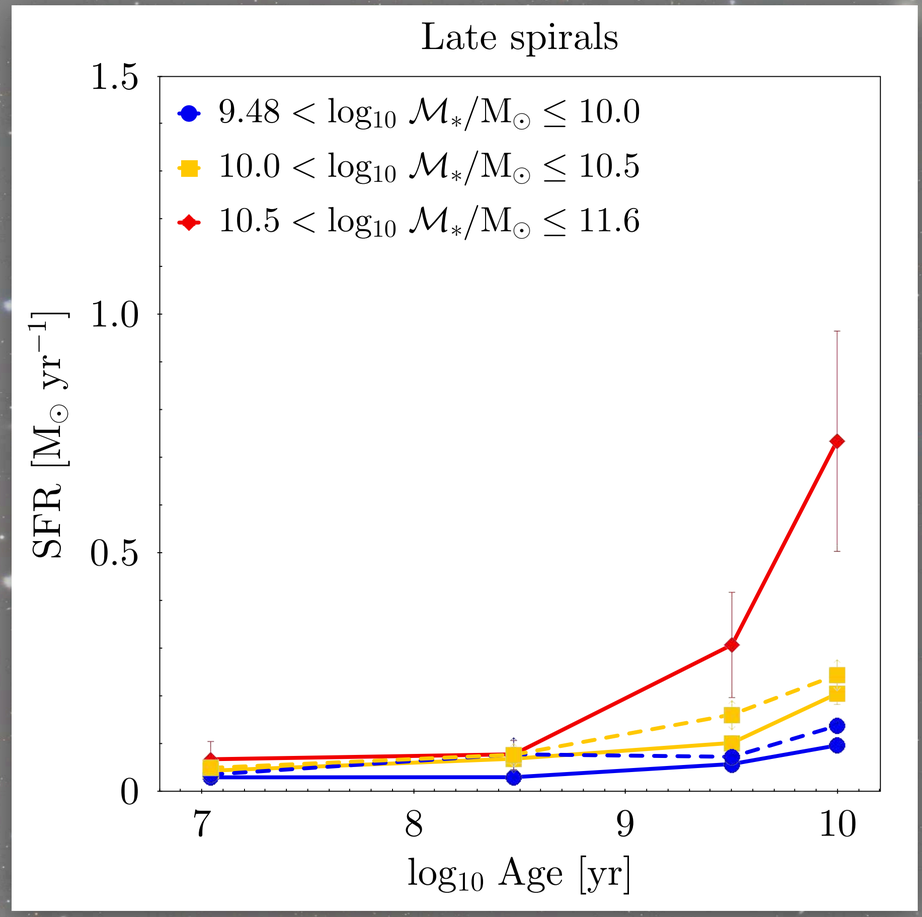
Downsizing effect!

Is stellar mass the most important factor?

SFH and stellar mass

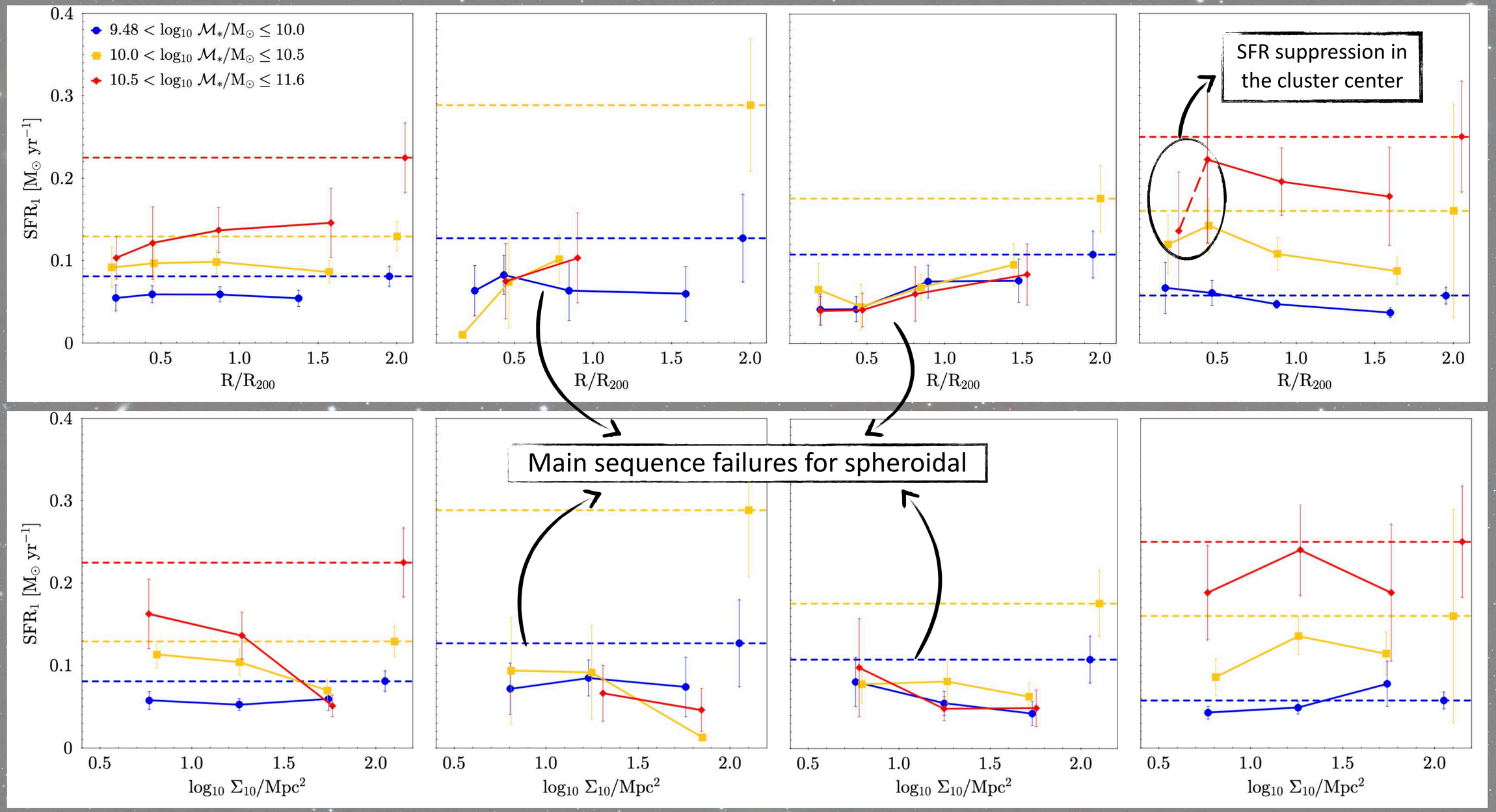


SpE

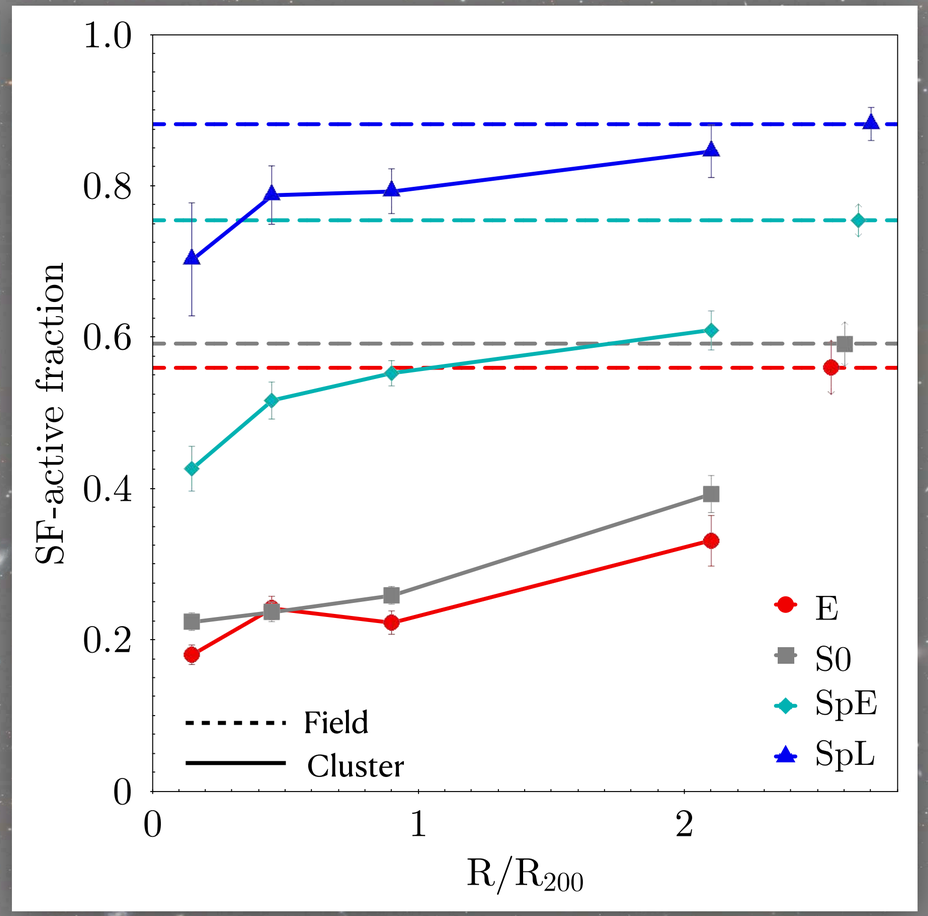


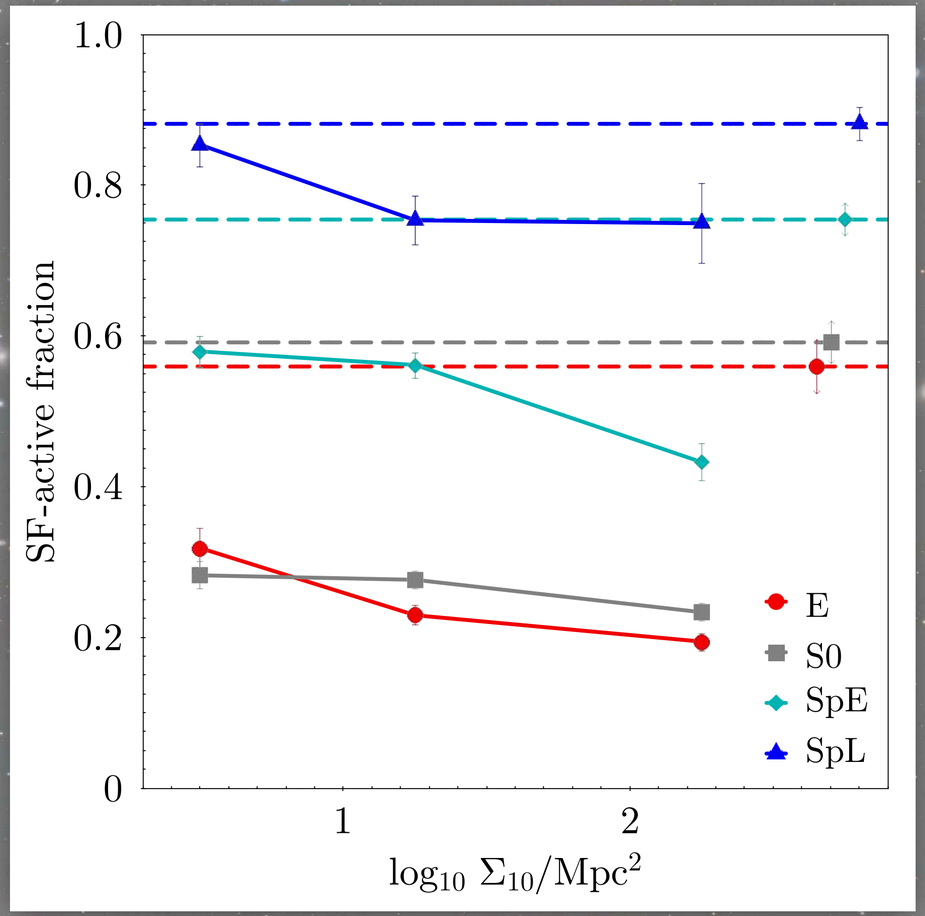
SpL

SFR vs. projected distance, local density



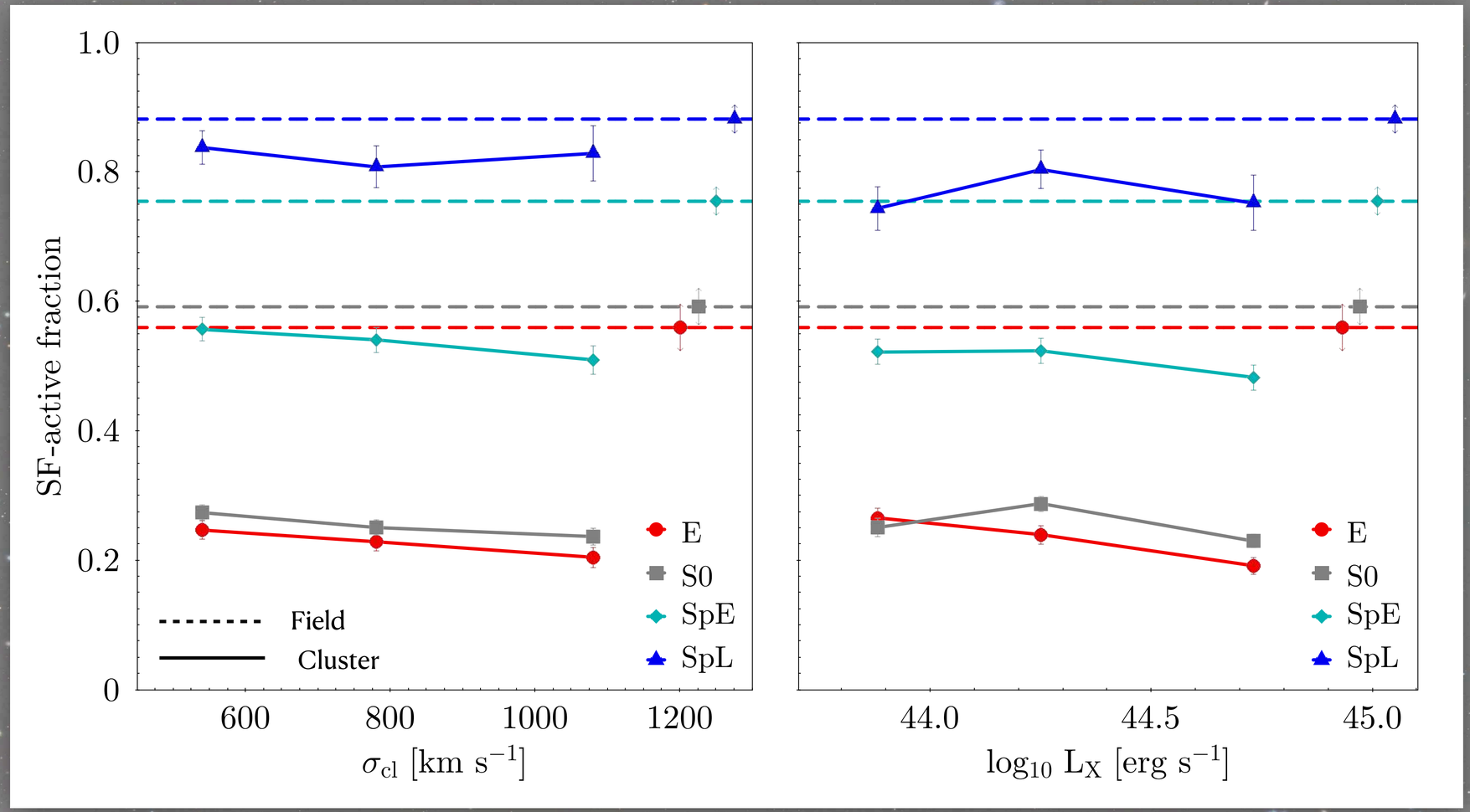
Quenching and local environment





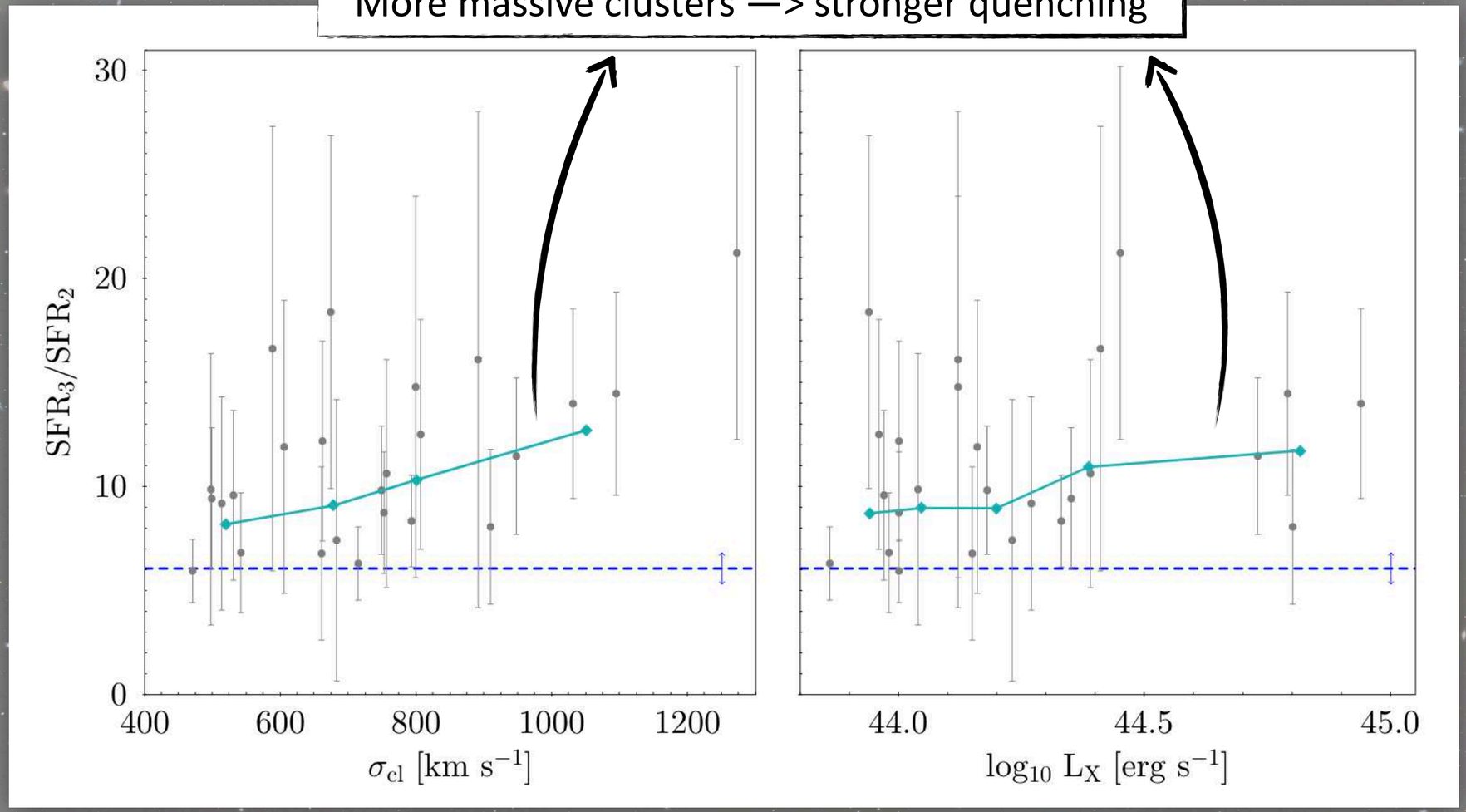
- Quenched if SFR $< 10^{-3}$ $M_\odot$ yr^{-1}
- SFR of E: possible overestimation due to other processes (low-luminosity AGN)

Does the global environment matter?



Quenching and global environment

More massive clusters —> stronger quenching



Field
Cluster

SFR_i	Age range
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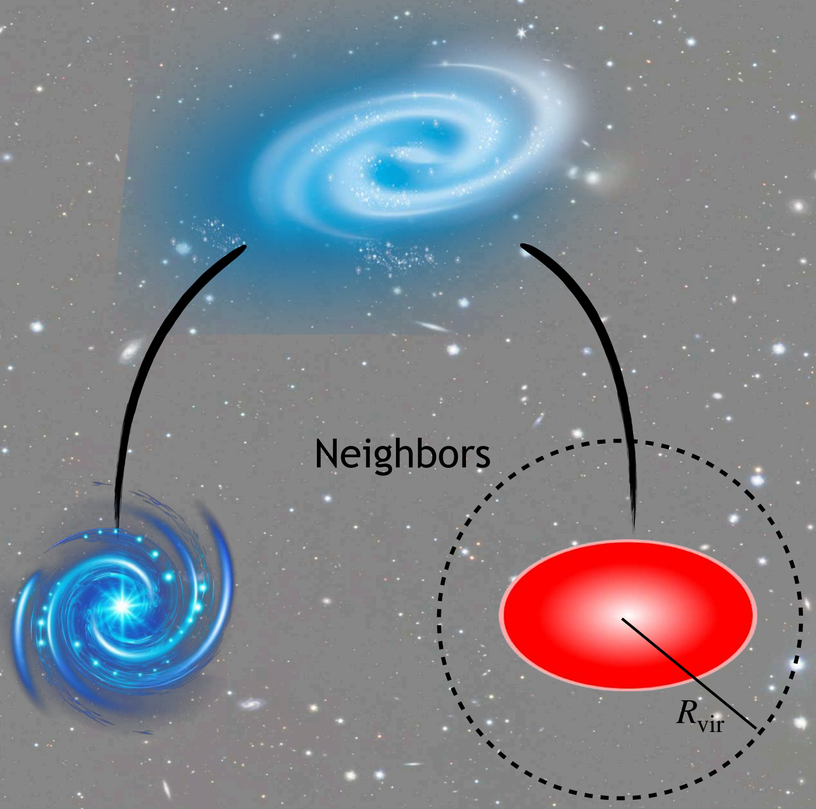
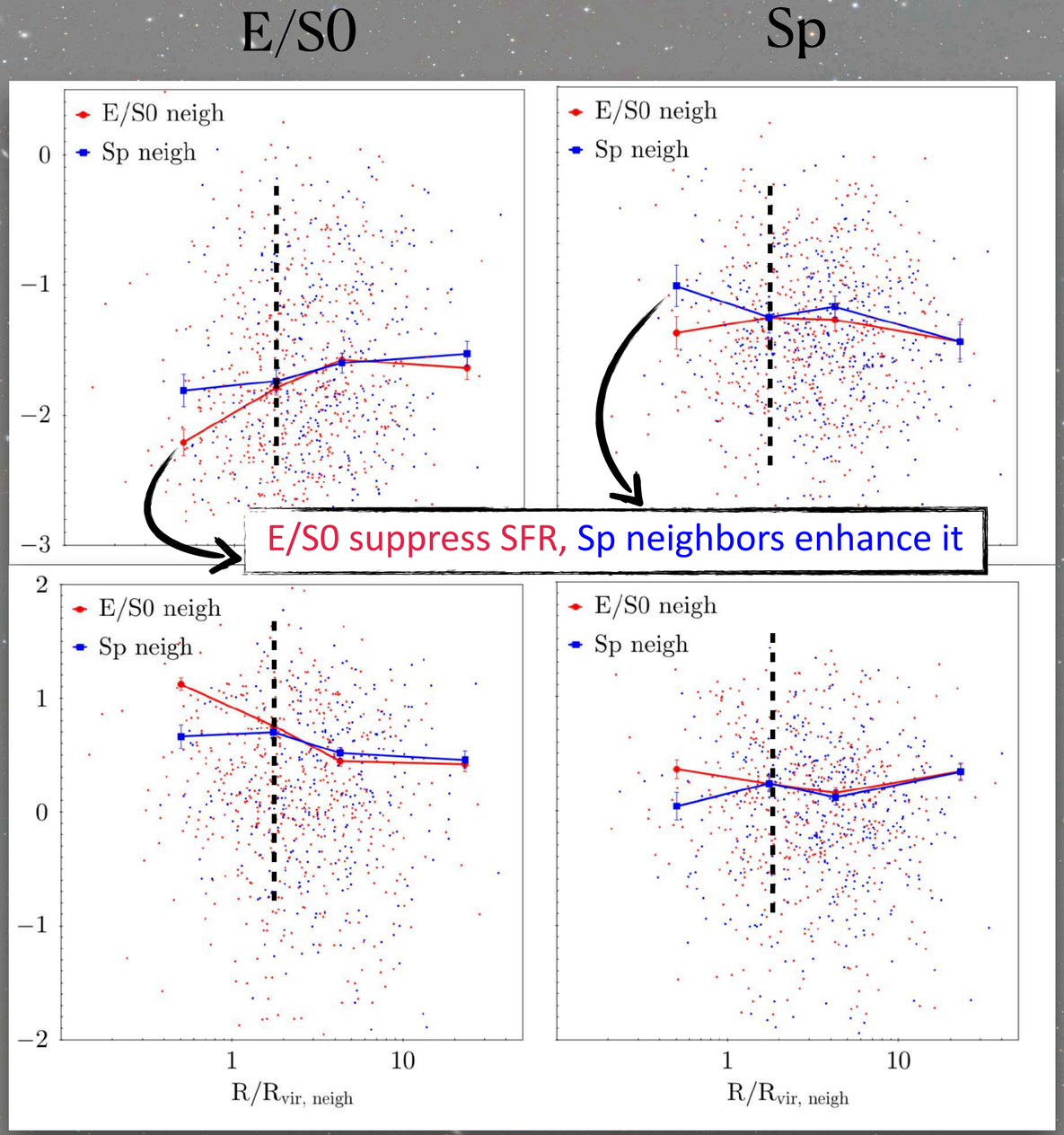
SFR_2	$19.95 - 571.5$ Myr
SFR_3	$0.5715 - 5.754$ Gyr
SFR_4	$5.754 - t_u$ Gyr

The influence of the nearest galaxy





To take home...

- ☑ SFH in clusters steeper than in field at fixed mass and morphology: pure environmental effect!
- ☑ Morphology is essential when studying SFH. Not taking it into account will lead to incorrect results.
- ☑ Quenching effects on spiral galaxies are stronger in more massive clusters: combination of local effects!
- ☑ Very close late-type neighbors will promote SFR, while early types will quench it.
- ☑ Clusters can both enhance and quench SFR on short timescales.
- ☑ More complete spectroscopy surveys of galaxies (IFUs!!!) will allow to study the stellar and gas dynamics, further helping to disentangle the different mechanisms at play.

Submitted to MNRAS as:
Pérez-Millán et. al.

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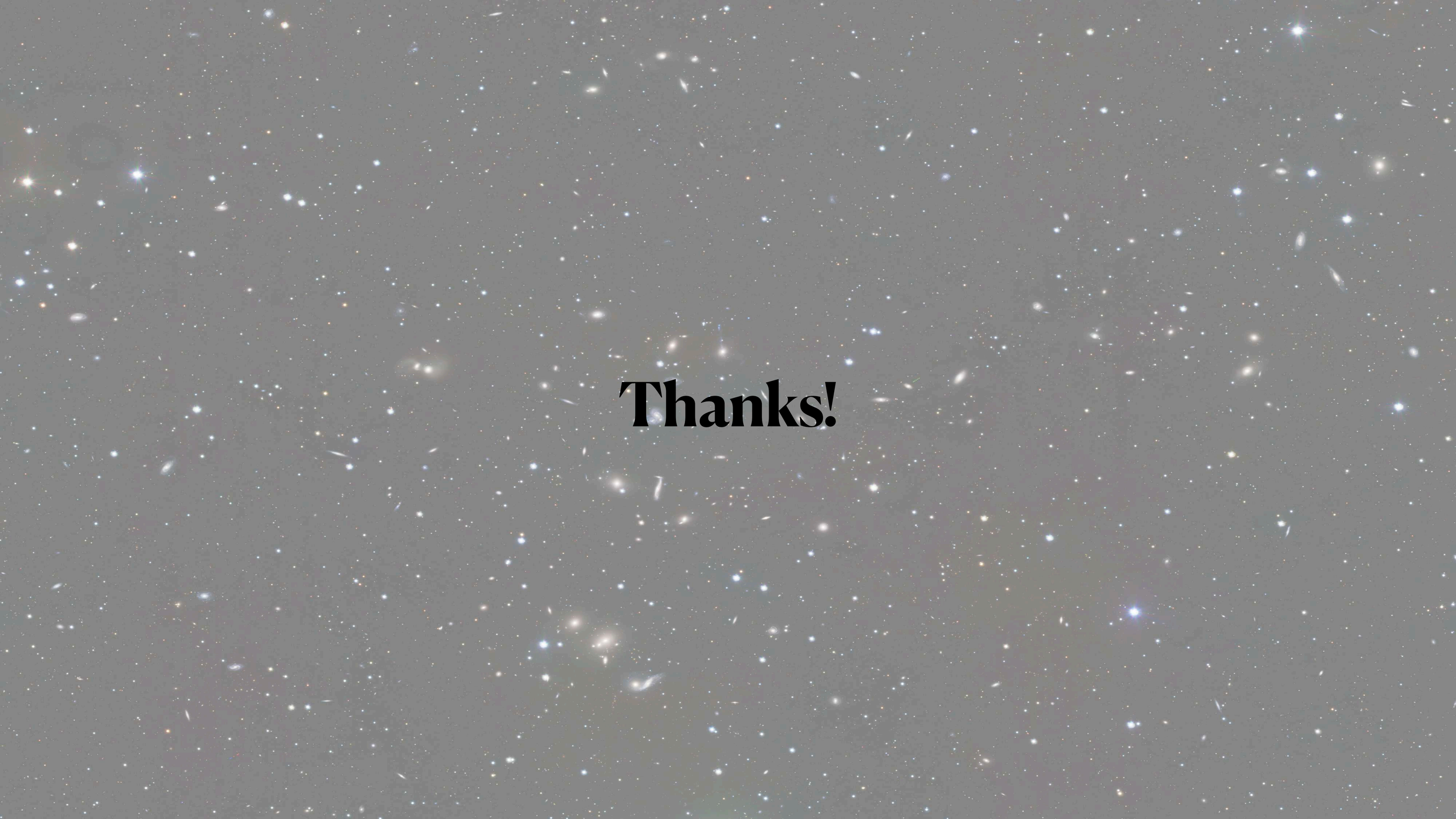
Thanks!